

Improving Sub-Seasonal to Seasonal Precipitation Forecasting for Water Management



WESTERN
STATES
WATER
COUNCIL

Will this winter be wet or dry?

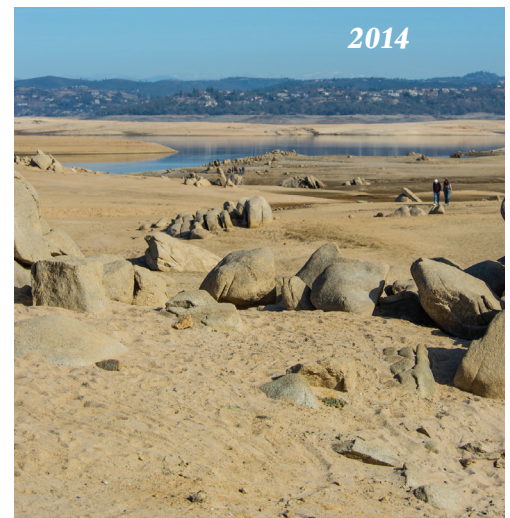
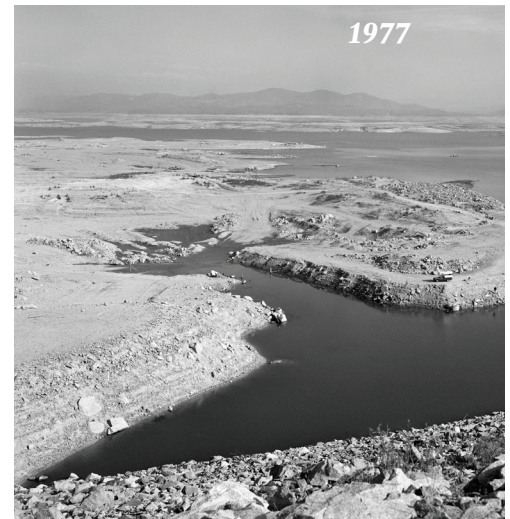
This is a critical question asked every year by state, local, and federal agency water managers, as well as by cities, farmers, and hydroelectric powerplant operators. Although the skill of conventional weather forecasts (which go out as far as two weeks in advance) has greatly improved over the past several decades, the same cannot be said for the critical longer-term forecasts important for water management. These longer forecasts – called sub-seasonal to seasonal (S2S) forecasts by atmospheric scientists – span time periods of several weeks out to a year. The skill of currently available forecasts, such as those produced by the National Weather Service's (NWS') Climate Prediction Center (CPC), is only slightly better than chance.

The Western States Water Council believes that current skill in S2S forecasting is not adequate to support water management decision-making, and **that the federal government should place a priority on improving S2S precipitation forecasting capability to support water management.** Water is the life-blood of the West, which experiences far greater variability in annual precipitation than does the eastern half of the country. Managing water in the West is about managing for the extremes of droughts and floods, and the need to store water when available to manage it during dryer times for cities, farms, and the environment. Better longer-term precipitation forecasts are a necessary tool for more efficient resource management.

As documented by NOAA's National Centers for Environmental Information, disasters at both wet and dry extremes of

The U.S. Bureau of Reclamation's

Folsom Lake: *Low water levels at Folsom Lake in 1977 (a strong El Niño year, and California's driest year of record) and in 2014 (an ENSO-neutral year, and one of the state's driest years). The CPC's outlooks rely heavily on the El Niño-Southern Oscillation (ENSO) as a source of predictability. Scientists believed that a strong El Niño would result in dry winter conditions in the Pacific Northwest and wet conditions in California, especially in Southern California. CPC's early winter forecast in 2014 called for a weak to moderate El Niño with above-normal precipitation for California; ENSO conditions were neutral and California had one of its driest years on record. In 2015, CPC correctly predicted the onset of strong El Niño conditions, but the expectation of a wet Southern California and dry Pacific Northwest was met with the opposite conditions, illustrating how much work remains to be done to improve seasonal forecasting.*



Flooding in the Pacific Northwest:

November 2015 flooding in Snoqualmie, Washington. According to climate scientists' understanding of canonical strong El Niño conditions, winter 2015-16 in the Pacific Northwest should have been dry. It was not, and parts of the region experienced greatly above-average precipitation.



Comparative variability of Western precipitation

Coefficient of Variation, Water Year 1951-2008

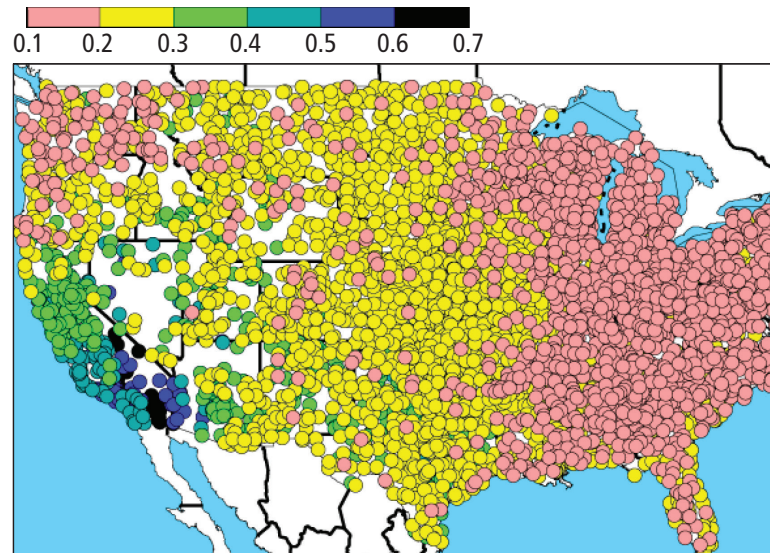


Figure provided courtesy of Mike Dettinger, USGS

An emergency temporary pumping plant for the Lake Don Pedro Community Services District floats on a depleted Lake McClure in early 2015.



Examples of Sub-Seasonal and Seasonal Water Management Decisions

Sub-Seasonal Decisions:

Will the rest of this winter be wet or dry?

- » How much water will we be able to provide to our wholesale customers this spring? When can we plan to make an announcement?
- » Will we hit hydrologic shortage triggers that require extraordinary conservation measures, or a need to negotiate contracts or adopt special regulations?
- » Could we have an unusually wet late spring that would result in elevated flood risks? When should we plan to begin special flood emergency preparedness operations?
- » If it looks like the rest of the winter will be dry, can we use some reservoir flood control storage space to save more water for our customers?
- » The winter has been very dry through December, are dry conditions likely to persist the rest of the winter?
- » When will we have to begin curtailing surface water diversions on intensively-used or over-appropriated rivers?

Seasonal Decisions:

Will this winter be wet or dry?

- » Do we need to seek additional drought response funding, reprogram other funds, or raise water rates? Do we need to budget for enhanced water conservation outreach activities?
- » Should we make plans and adopt regulations for operating a drought water bank? Should we purchase supplemental water supplies from groundwater or other sources to be able to meet our needs?
- » Should we begin negotiating contracts for one-time sale of surplus wet-weather water? Can we set up a temporary groundwater recharge and banking program to take advantage of expected wet conditions?
- » Should we intensify flood fighting training and emergency preparedness outreach in vulnerable areas?

the hydrologic cycle are responsible for billions of dollars in losses. Water managers at state, local, and federal levels could employ improved S2S forecasts to prepare for and respond to drought and flooding, reducing losses. Similarly, decision makers in other sectors affected by water management (agriculture, hydroelectric power generation, emergency management) share a common interest in more skillful and useful forecasts.

Historically S2S forecasting has occupied a research gap in between conventional numerical weather modeling and the century-scale climate modeling performed to evaluate global change. Significant scientific progress has been achieved at both the weather and century-scale ends of this spectrum, thanks to ongoing federal

Next Generation Earth System Prediction: Strategies for Sub-seasonal to Seasonal Forecasts

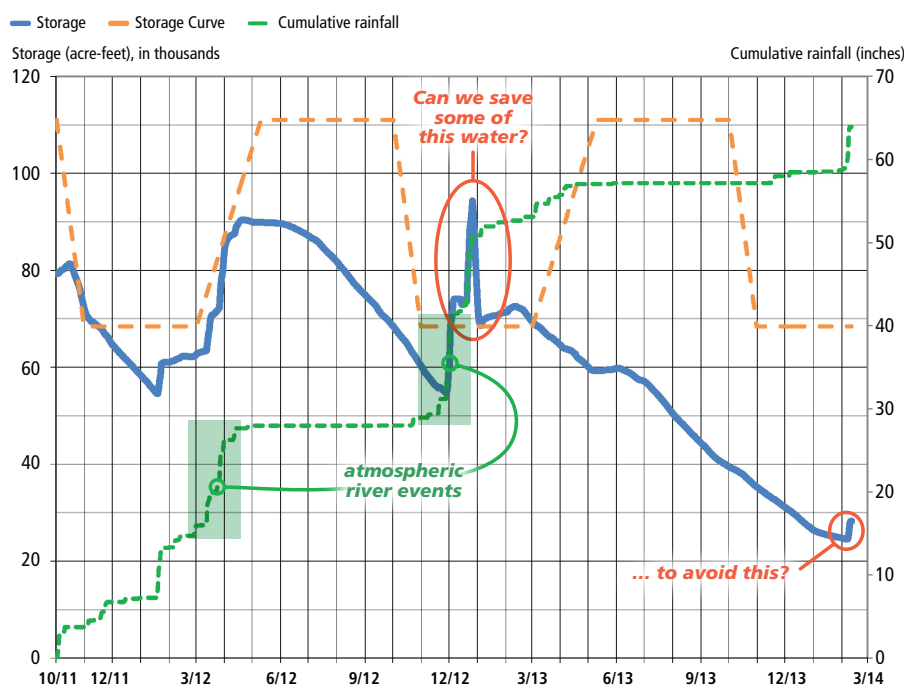
In 2016 the National Academy of Science released a report on a national research agenda for improving S2S forecasting. The report identified four key strategies for the next decade:

1. Engage users in the process of developing S2S forecast products
2. Increase S2S forecast skill
3. Improve prediction of extreme and disruptive events
4. Include more components of the earth system in forecast models

It also made 16 specific recommendations for a research agenda, some of which include:

- » Establish an ongoing and iterative process in which stakeholders, social and behavioral scientists, and physical scientists co-design S2S forecast products.
- » Identify and characterize sources of S2S predictability, including natural modes of variability, slowly varying processes, and external forcings.
- » Focus predictability studies, process exploration, model development, and forecast skill advancements on high impact S2S forecasts of opportunity that particularly target extreme events.
- » Maintain continuity of critical observations, and expand the temporal and spatial coverage of in-situ and remotely sensed observations beneficial for operational S2S prediction.

The report notes that: “More skillful and useful S2S forecasts – developed through sustained engagement with users and advances in basic knowledge and technological capabilities – could radically improve the basis for decision making on S2S timescales. There are also emerging science and technical capabilities that make rapid advances in S2S forecasts more likely than envisioned even 5 years ago.”



A pilot project to evaluate use of forecast-informed reservoir operations on California’s Russian River is being carried out by Sonoma County Water Agency in partnership with the U.S. Army Corps of Engineers, other federal and state agencies, and university researchers. This river basin has historically been vulnerable to both flood and drought extremes, and special status fish species protection requirements further complicate reservoir management. With atmospheric river storms accounting for 80 percent of the variance in basin precipitation, this river offers a unique opportunity to test applicability and skill of forecasting improvements.

Figure courtesy of Sonoma County Water Agency

Low water levels at Hoover Dam: The Colorado River Basin has experienced prolonged drought conditions, resulting in declining reservoir elevations in Lake Mead and Lake Powell. Water agencies in the seven Colorado River Basin states have been taking unprecedented steps to manage the risk of shortage in this interstate and international basin.

Water users in the Lower Basin have developed a voluntary program for extraordinary conservation measures that leave more water in Lake Mead to lessen the risk of declining reservoir levels that would hit a shortage trigger elevation, requiring delivery curtailments. Upper Basin water users are studying contingency measures upstream of Lake Powell to avoid reaching water levels that would trigger emergency actions to protect a minimum hydropower generation pool. Risk management programs such as these cost money and/or water. Skillful seasonal precipitation forecasts would help support decisions to balance costs against risks of shortage.



2011 Missouri River flooding in North

Dakota: Record precipitation in the Missouri River Basin and adjoining areas in the Rocky Mountains and High Plains in the late spring of 2011 had been preceded by record or near-record winter snowpack, setting up conditions for major flooding in Council member states of Montana, North Dakota, South Dakota, and Nebraska, and causing over \$2 billion in damages. An estimated 11,000 people were forced to evacuate Minot, North Dakota due to high water on the Souris River, and areas surrounding the state capital of Bismarck were flooded. Improved forecasting at the sub-seasonal to seasonal timescale would be useful for informing flood risk management in river basins like the Missouri where travel times for reservoir releases are measured in weeks and long lead times are needed to move very large flood volumes down a defined channel.



Fallowed land in California's San Joaquin Valley: Drought-fallowed field in California's San Joaquin Valley in 2015. Agriculture is the largest use of developed water supplies in the West, representing 70–80 percent of total water use. Growers need lead time for making their final seasonal planting decisions, which must factor in expected water availability and risks due to possible shortages. Skillful sub-seasonal forecasts would allow water suppliers to give growers better late winter estimates, allowing them to make the most efficient use of available resources and to identify alternative sources to sustain permanent plantings such as orchards and vineyards during droughts.



investment. According to the American Meteorological Society, the skill, for example, of five- to six-day NWS temperature forecasts in 2012 is equivalent to that of three- to four-day forecasts in 1992. Substantial federal support from 1990 onwards for the U.S. Global Change Research Program has also resulted in major progress in developing increasingly complex climate models. However, similar progress and investment have not occurred at the S2S time scale and is greatly needed. As the National Academy of Science said in its 2016 report on strategies for improving S2S forecasts: "... an associated U.S. national research agenda aimed at strengthening the contributions of S2S forecasts to public and private use activities has not yet emerged".

Lead time is critical in making water management decisions. Improving seasonal precipitation forecasts would provide longer lead times for decision-making. Longer lead times are especially useful in planning and managing for the extremes of droughts and floods. Skillful forecasts would also allow for more efficient operation of water infrastructure, such as balancing reservoir operations between the competing objectives of flood control and water storage. Absent good predictive capability several weeks ahead, for example, reservoir operators must manage as conservatively as possible to ensure that space will be available to hold winter-spring runoff and manage floods. Better forecasts would allow

operators to retain more water in storage, especially later in the spring, for summertime uses while still providing flood protection – the equivalent of developing a new water supply at minimal cost. Lead time is also needed for many other actions related to preparing for and responding to wet and dry conditions, including negotiating water transfer contracts, obtaining environmental regulatory approvals, administering modifications to state water rights, and helping water agencies negotiate voluntary agreements to meet critical needs in times of shortages.

The 2016 National Academy of Science’s report has identified a path forward for improving S2S forecasting. This report, as well as a previous 2010 report on intraseasonal to interannual prediction, found that multiple opportunities remain to be fully exploited in order to improve prediction skill, including better understanding of ENSO, the Madden-Julian Oscillation (MJO), the Arctic Oscillation, and land-atmosphere interactions and feedbacks.

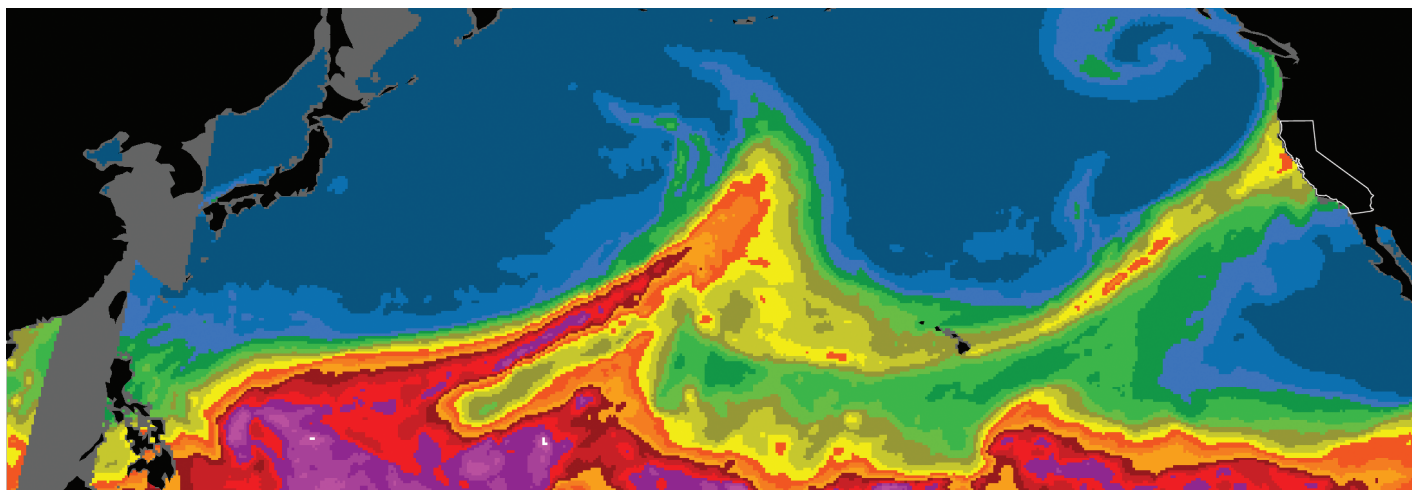
National Weather Service

California Drought – 2014 Service Assessment

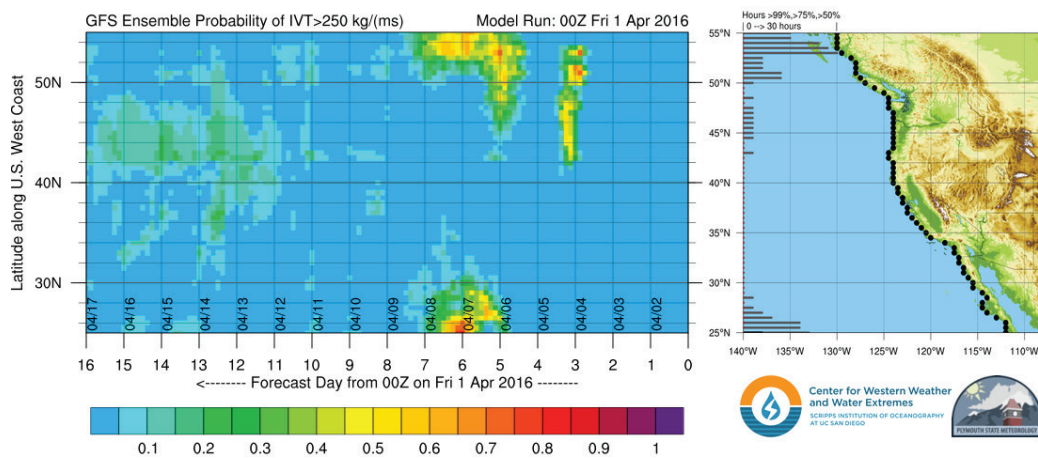
In 2015 NOAA released its first-ever service assessment for drought, for the California drought which was in its third year at the time of assessment preparation. NOAA conducts service assessments to evaluate its performance after significant hydrometeorological, oceanographic, or geologic events. The assessments are triggered by factors such as major economic impacts to a large area or population, or extensive national public interest. Assessments are used to evaluate the effectiveness of products and services made available to stakeholders, to help NOAA continuously improve the services it provides. The drought assessment’s top outcome was the input received from numerous stakeholders regarding the need for seasonal prediction capability focused on cool season mountain precipitation, both in California and in the Colorado River Basin.

“A majority of the stakeholders interviews for this assessment noted one of the best services NOAA could provide is improved seasonal predictions with increased confidence and better interpretation. These seasonal precipitation products, produced by NOAA’s Climate Prediction Center (CPC), are national in scale and are not designed to provide regional forecast information – information which is most relevant to decision makers interviewed by this team. For instance, state and federal officials managing California’s water supply have a major unmet need for skillful predictions targeted at cool-season snowpack for the Sierra Nevada Mountains.”

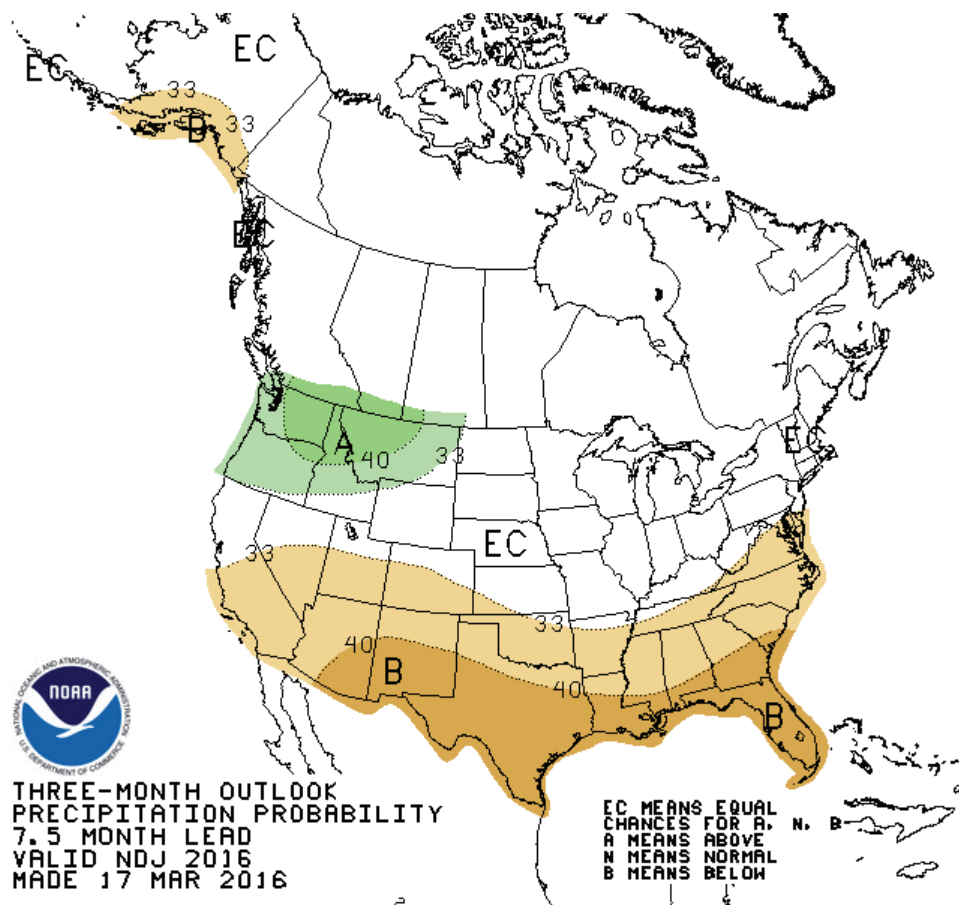
Atmospheric river storms – storms fueled by concentrated streams of water vapor from the Pacific Ocean – are big contributors to annual water supply conditions, as well as potential sources of major floods. Image courtesy NOAA Hydrometeorology Testbed.



This research product from the Center for Western Weather and Water Extremes at the Scripps Institution of Oceanography shows the magnitude, probability, and timing of atmospheric river conditions along the West Coast based on NOAA's Global Ensemble Forecast System weather model. Although the weather model is run out to 16 days, its skill after the first week is low. One pathway to improving S2S forecasting is to improve the ability to predict atmospheric river storms at longer timescales.



An example of the precipitation seasonal outlook products now produced by NOAA's CPC.



Specific to the West in particular, we need to better understand predictability of atmospheric river storms – a type of storm fueled by concentrated streams of water vapor from the ocean. Recent research has highlighted the important role that these storms play with respect to extreme precipitation. For example, emerging information suggests that potential relationships between MJO conditions and atmospheric river storms may provide one means of improving near-term forecast skill at certain times.

The vision in the National Academy of Science's 2016 report that S2S forecasts could be as widely used a decade from now as conventional weather forecasts are today needs to be made a reality.

The Western States Water Council asks that the federal government prioritize additional resources to move forward with more research, observations, and operational weather modeling to provide necessary support for near-term improvement in S2S precipitation forecasting for water management.

Member states:



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